Global Journal of Science Frontier Research
Environment & Earth Science
Volume 13 Issue 4 Version 1.0 Year 2013
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Estimation of Aquifer Parameter of Pabna District, Bangladesh

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Abstract- The amount of groundwater in any area depends on the characters of the underlying aquifer, its extent and the frequency of discharge. Quantitative hydro-geological studies of aquifer parameters are important pre-requisites for scientific management of groundwater resources. Lithological data can be used as an important source for hydro-geological investigation.

In this work, the lithological character encountered in borehole of 303 locations and static water levels of 81 locations have been collected, compiled, processed, analyzed and interpreted for studying the hydro-geological properties of nine upazillas of Pabna district, Bangladesh. Various types of map of hydro-geological properties of subsurface formation like porosity, specific yield, transmissivity, hydraulic diffusivity have been prepared for the proper identification of groundwater occurrence, distribution and potentiality of the area studied. Porosity and specific yield are the two important properties of an aquifer material to identify the storage of the aquifer. The yield determines whether or not the water saturated zone is a source of groundwater and the natural characteristics of the water bearing formations affect the yield. The transmissivity map represents its average water transmitting property which depends mainly on the number and diameter of the pores present and determines the effectiveness of groundwater reservoir. Hydraulic diffusivity determines the time that is need for a given head change to occur in an aquifer as a response to a great change in head at another point. Finally, groundwater potential zones have also been identified for groundwater exploration.

GJSFR-H Classification : FOR Code: 050299, 780104

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I. Introduction

Groundwater is the only source of water supply for drinking and main source of irrigation in the area studied. Water scarcity is found in this proposed area during irrigation period due to the increasing population and development activities. The increasing population has suddenly increased the demand for consumption of water and stimulated investigations oriented towards quantifications of this resource. The large scale abstraction of groundwater for irrigation without proper planning and management has caused many environmental degradation. So, a detailed study is now essential for the conservation of this important resource in the area.

Aquifer parameter of subsurface formations plays an important role for groundwater occurrence, distribution and reservation. These parameters can be classified in two categories. One of them is formation parameter and the other is hydro-geologic parameter. Formation parameters are very important for groundwater investigation and detection of its condition. Detection of effective groundwater reservoir, measurement of the rate of propagation of groundwater, selection of suitable well-sites etc. are important for groundwater development .Hydraulic conductivity transmissivity, hydraulic diffusivity and radius of influence are the measuring instruments for the identification and estimation of the hydro-geologic parameters. Those parameters have been estimated and presented in the form of contour maps. So the estimation of various types of aquifer parameter would definitely identify the actual feature of groundwater in the study area.

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II. Materials and Methods

Any successful research does not depend not only upon the availability and quality of requisite data but also on the appropriate methodology. It is not possible to identify and estimate the invisible properties of subsurface formations. Because it is far beyond the access of direct visual measurement and experiment. So present research work has conducted and completed through data acquisition. Analysis has been made on integrated hydro-geological approach. About 303 borehole data and static water level data of 81 locations during the period of 1994-2007 have been collected from various relevant organizations for the measurement of aquifer parameters. Borehole data would provide valuable information of subsurface water bearing formations and help to estimate the different types of aquifer parameter of the investigated area.

III. General Feature s of the Study Area

The study area, Pabna district, is located in the south-eastern corner of greater Rajshahi division (Fig.1). The area comprises nine upazillas covering 2371.50 Sq.km. The two major rivers, the Padma and the Jamuna, are flowing along the boundaries of the study area sustaining the environmental balance and socio-economic development (ZUP,2005). The entire study area is almost a plain land of an average elevation of 14m whereas the northwestern part is slightly more elevated with maximum elevation of 22m.The investigated area is located in the shelf region zone of

Bangladesh and was formed by the deposition of sediments carried by the river Padma and its tributaries in the Pleistocene age. The alluvium is composed of clay and sand of different grains. The overall soil quality is suitable for groundwater potential. The topmost formation, composed of clay and silt, is underlain by fine, medium and coarse sand. The aquifer system in the investigated area may be schematized into an aquifer of variable thickness.

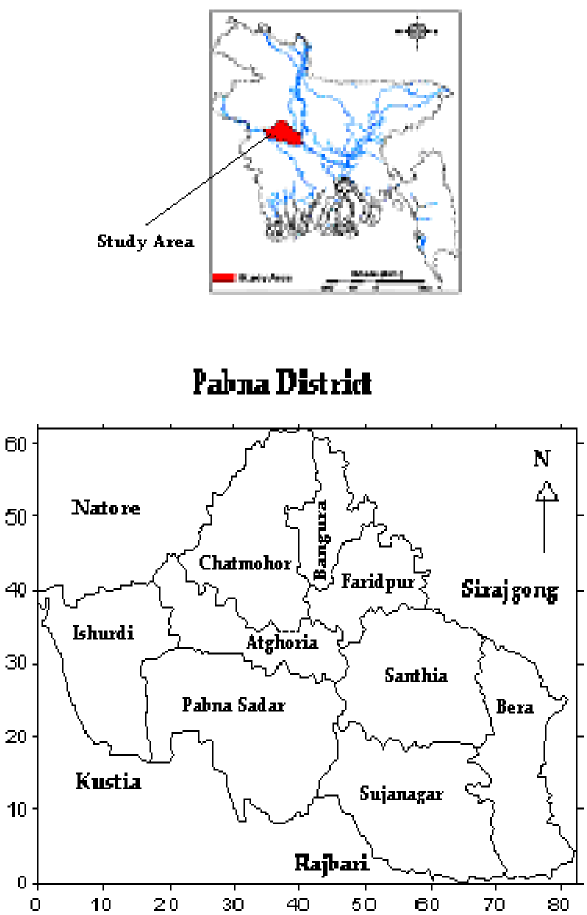

Figure 1 : Representation of the study area map

IV. Analysis of Litholog Data

The development of groundwater requires knowledge about the characteristics of the subsurface aquifer parameters. So, analysis of litholog and static water level data are very important for the measurement of aquifer parameters. In this context, the distribution of borehole locations along with static water level positions in the study area has been shown in Fig.2.

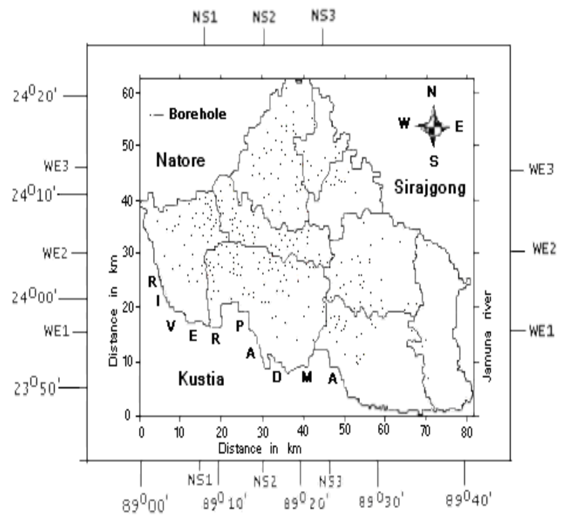

Figure 2 : Area under investigation showing borehole locations

V. Porosity

The groundwater can get stored in the underground rock, only if, they are sufficiently porous, because the water is actually stored in the pores of the rocks. Porosity is the measure of the volume of void spaces in geological formation and it is also a measure of absorptive power of the material. In terms of groundwater supply, granular sedimentary deposits are of major importance of porosity. Porosities in these deposits depend on the shape and arrangement of individual particles, distribution by size and degree of cementation. Fig.3 shows the distribution of average porosity which ranges from 38% to 43%. From the figure it is observed that the average value of porosity is maximum in the east-southern part of the area studied. The lower range of porosity in between 35.50% to 38% occupies some discrete places in a scattered way. The porosity of the geological formations of the area indicates a good reserve of groundwater which could be explored.

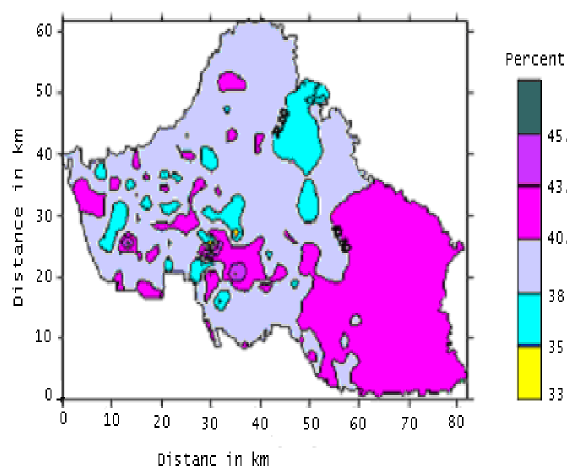

Figure 3 : Representation of porosity in the study area

VI. Specific Yield

The term specific yield is defined as the volume of water released by the downward movement of a unit distance. According to Meizner (1923) specific yield is the ratio of volume of water that drains from a saturated rock owning to the attraction of gravity to the volume of the rock. The specific yield depends upon the composition; the more sand in the sediments the higher the specific yield. The higher the clay content, lower the specific yield.

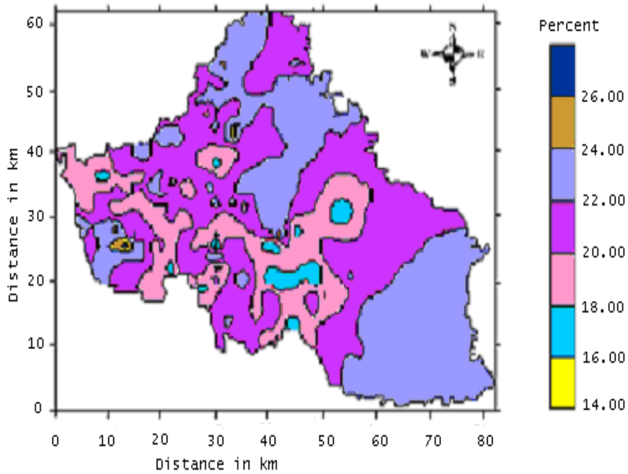

Figure 4 : Representation of specific yield in the study area

The specific yield of the study area has been estimated from the borehole and static water level data. A shaded contour map of specific yield has prepared depending upon the representative values of specific yield and the saturated thickness of the formations as shown in Fig.4. From the map it is observed that the specific yield values change from 18% to 24%.The values of specific yield in between 22% to 24% are found in the southeastern portion and in the north region. There is also a small pocket in the southern part of Ishurdi upazilla of the study area. The specific yield values of 20% to 22% are observed in north-east and north-west regions. There are some pockets of the range of 18% to 20% are identified in the west and south regions of the area. From the observations, it is found that the existing aquifer in the study area is unconfined in nature and it can be concluded that the overall values of specific yield of the area is suitable and satisfactory for groundwater potentiality.

VII. Specific Retention

The quantity of water retained by the material against the pull of gravity is termed as the specific retention. The specific retention is the amount of water held between the grains due to molecular attraction. The amount of this water will depend upon the total interstitial surface in the rock. If the total interstitial surface is more, the specific retention will be more and vice versa. The specific retention of the study area has been estimated from the lithologic data and a shaded contour map has been prepared at an interval of 2.5% as shown in Fig.5. From the figure it is observed that a track extended from north-east to south-west having the specific retention higher and its value ranges from 19.50% to 22%. The north-west and south-east part of the study area have the specific retention of medium type of 17% to 19.50%. The lowest value of specific retention is found in the upper portion of northeastern part of the study area. Besides, there are some pockets of the lower value of specific retention distributed in a scattered form. The areas containing the lower specific retention indicate the suitable regions for groundwater exploitation. Some small regions of the study area have the highest (above 22%) value of specific retention. These regions are not suitable for better exploitation of groundwater.

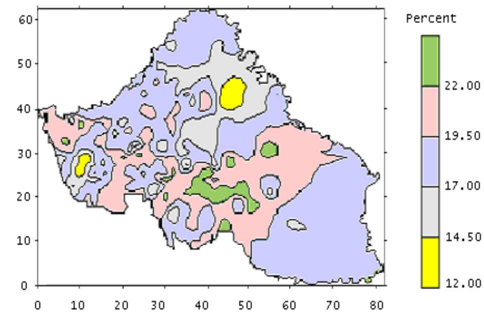

Figure 5 : Distribution of specific retention of the study area

VIII. Hydraulic Conductivity

The hydraulic conductivity of a water saturated zone represents its average water transmitting property which depends mainly on the number and diameter ofthe pores present. It may be classified in two parts: one of them is vertical conductivity and the other is horizontal conductivity.

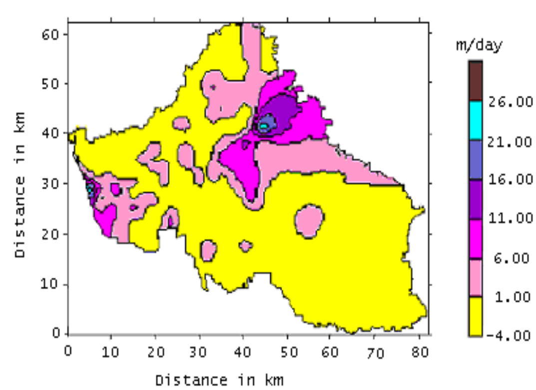

Figure 6 : Distribution of vertical conductivity in the study area

A shaded contour map of vertical conductivity has been prepared from the estimated values using the borehole litholog data as shown in the Fig.6. It is observed from the figure that the vertical conductivity of the most part of the study area is very low. The northeastern and the southwestern parts of the investigated area have the higher value of vertical conductivity. Some pockets of the higher value are shown in the figure. The higher value of vertical conductivity indicates the higher recharge area.

Another shaded contour map of horizontal conductivity of the investigated area is shown in Fig.7. It is observed from the figure that the horizontal conductivity of the study area ranges from 10 m/day to 85 m/day. It is also observed that the south-eastern side of the study area have the minimum value of horizontal conductivity and this observation indicates that the area is not good for groundwater resource. From the analysis it can also be concluded that heavy runoff occurs in this place due to the slopping nature of the surface and the bulk thickness of clay formation. So, the area is less potential for groundwater exploitation. The rest parts of the study area have the suitable range of horizontal conductivity and the groundwater recharge condition is suitable and satisfactory.

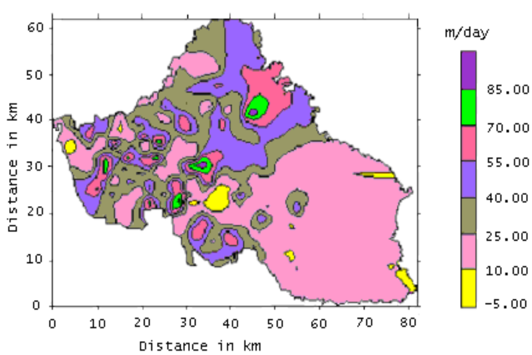

Figure 7 : Distribution of horizontal conductivity in the study area

IX. Transmissivity

Any water saturated zone could be used for exploration if the formation permits the flow of water through it. The hydraulic conductivity of a water saturated zone represents its average transmitting property, which depends mainly on the number and the diameter of the pores and fluid characteristics. It is the product of mean aquifer thickness and mean aquifer permeability, decreasing aquifer thickness will cause a decrease in transmissivity for the same type of sand and lower mean permeability cause by train towards fine or poorly sorted sand will have the same effect.

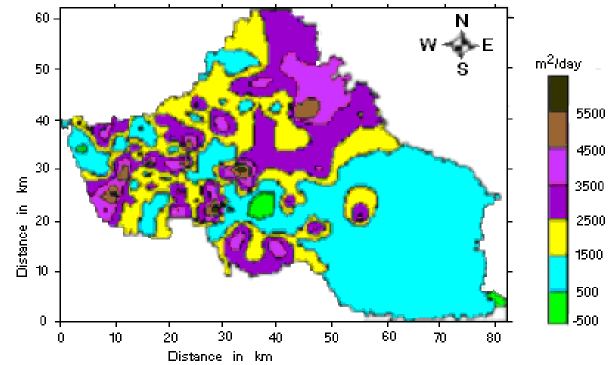

Figure 8 : Distribution of transmissivity in the study area

The value of transmissivity has been studied using the borehole information. In the present study, transmissivity of water in the saturated formation has been taken into account. Considering the thickness of the layer of different grain size as obtained from the borehole data and the corresponding hydraulic conductivity, the transmissivity in different layers have been calculated. Then the individual values are added to get the transmissivity of that location. The value of transmissivity in the study area has been estimated and presented in the form of shaded contour map at the interval of 1000 m^2/day as shown in Fig.8. The figure illustrates a high contrast of transmissivity over the area, which ranges from 500 m^2/day to 3500 m^2/day. In southeastern part of the area, the value of transmissivity covers 500 m^2/day to 1500 m^2/day. In the north-eastern part and the some discrete parts of western-southern side of the study area the value of transmissivity is the highest. The transmissivity of the rest of the area is within the range of 1500m^2/day to 3500m^2/day. It could be said that the estimated value of transmissivity of the aquifer is very much favourable for groundwater exploration.

X. Hydraulic Diffusivity

The ratio of transmissivity to the storage coefficient is defined as the hydraulic diffusivity (Karnath,1990). The hydraulic diffusivity is the rate of propagation of change in head in an aquifer. Actually this parameter indicates the regions having higher values are comparatively favourable for groundwater development due to small head change.

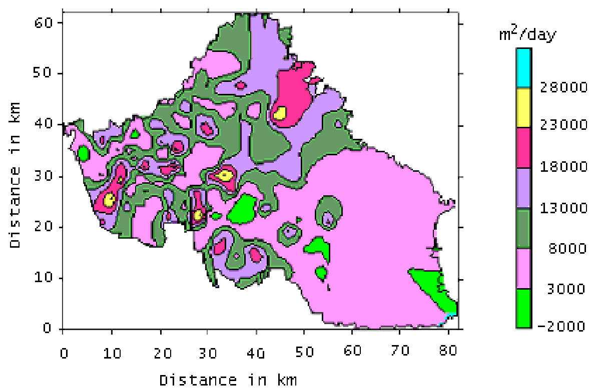

Figure 9 : Representation of hydraulic diffusivity in the study area

A contour map of hydraulic diffusivity has been prepared as shown in Fig.9. The major portion of the area covers the range of diffusivity from 3000 m^2/day to 18000 m^2/day. The southeast corner of the area having the value of diffusivity of 3000 m^2/day to 8000 m^2/day which covers above 50% of the entire area. The central, northern and western parts of the study area have the value of diffusivity from 8000m^2/day to 13000m^2/day, but it is not in a regular form.

XI. Radius of Influence

The radial distance from the centre of well to the limit where the drawdown is zero is called the radius of influence. Water to the extent of radius of influence from the well is under motion to fill up the pumping rate. Tube-wells have been generally located without any scientific studies, till recently. Pumping wells should be spaced far apart so that their cones of depression will not overlap over each other resulting in the reduction of their yields and /or increased drawdown. If two or more wells are constructed in such a way that they are near to each other and their cones of depression intersects, they are said to be interfere. Such mutual interference of wells decrease the discharge of the interfering wells (Garg,2004).

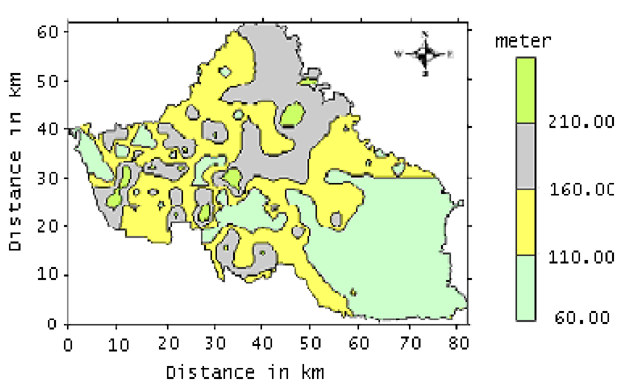

Figure 10 : Radius of influence of the pumping wells in the study area

A contour map of radius of influence is prepared depending upon the values of storage coefficient and the transmissivity as shown in Fig.10. As the aquifer of the study area is unconfined in nature, so the storage coefficient S is chosen as 0.21. From the figure it is observed that the value of radius of influence of the study area ranges from 60m to 210m. The southeastern part of the study area has the radius of influence of 60m-110m. Some portions of the northeastern side and the remaining parts of the study area have the radius of influence of 110m to 160m. But there are some pockets of various values of radius of influence almost all over the area except the southeastern part. A very few regions of the study area have the radius of influence of 160m-210m. From the observation it can be concluded that all the area except the southeastern part is suitable for well construction and exploration.

XII. Groundwater Potential Zone

The principal aim of the interpretation of borehole data and the preparation of different aquifer properties maps are to provide input information to the groundwater potential map (Krisnamurthy et.al,1992). Groundwater potential map can be prepared from the geometric properties of aquifer. A thick layer of coarse sand represents higher potential and a thin layer of fine sand with slit represents low potential. Therefore, groundwater potential of an area depends on the aquifer thickness and aquifer composition material. It is well known that groundwater head gradient plays an important role in exploration of groundwater. An area with high gradient of groundwater head means low conductivity and hence it is not suitable for bulk extraction. Therefore, suitable location for water-wells is the place, which is potential for groundwater and have low groundwater head gradient. A location is marked as suitable for water-wells if the location is potential for groundwater and has a good hydraulic permeability. A high gradient of groundwater head represents less permeability and a low gradient means high permeability.

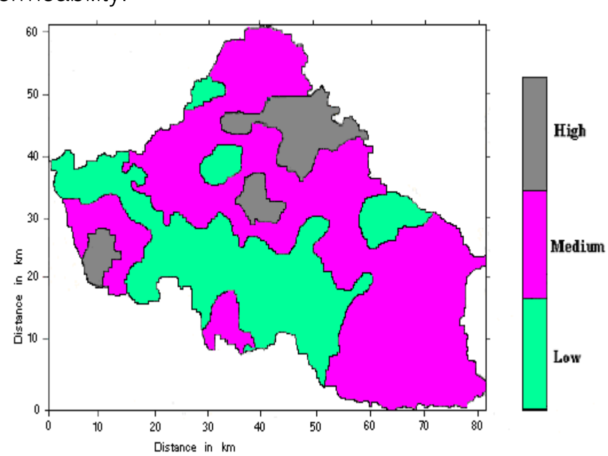

Figure 11 : Representation of groundwater potential zone in the study area

Groundwater potential map has been prepared on the basis of specific yield, transmissivity and yield index maps (Fig.11). Three zones are identified in the figure as high, medium and low potential. In general, that area could be identified as a medium potential zone. In the northeastern corner and two other pockets also identify as high potential zone. From the map it is observed that the brown portions of the investigated area are high potential and the orange portions are medium potential. A low potential profile is observed from west to the southeast portion in the study area. The blue portions of the investigated area indicate low potential area. In general, it could be said that the investigated area is favourable for groundwater exploration, but large scale abstraction of water should be avoided.

XIII. Conclusion

Borehole data have been processed and analyzed to estimate the hydro-geologic parameters of subsurface formations of the study area and presented in the form of maps. From the analysis it is clearly observed that various parameters have the values within the recognized limits. The overall thickness of the composite sandy formation is suitable for groundwater potentiality. No other impermeable layer is found below the sandy formation. Basically, the area is unconfined in nature. Porosity, specific yield, specific retention, transmissivity, vertical and horizontal conductivities, hydraulic diffusivity, radius of influence of the study area have been measured and presented with the contour maps. Finally, groundwater potential zone of the study area has been prepared for the detection of potentiality of the investigated area. From all the maps it is very clear that the hydro-geologic sub-surface properties of the investigated area are favourable for groundwater abstraction.

XIV. Acknowlegement

The work has been accomplished in the Geophysics Laboratory of the Department of Applied Physics and Electronic Engineering of Rajshahi University with the full co-operation of the institution of 'Panasi Project' under the department of Bangladesh Agriculture Development Corporation (BADC), Pabna, Bangladesh and the direct supervision of my guide who is appointed for this research work. I am very much grateful to the stated institution for giving us relevant information about the work.

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